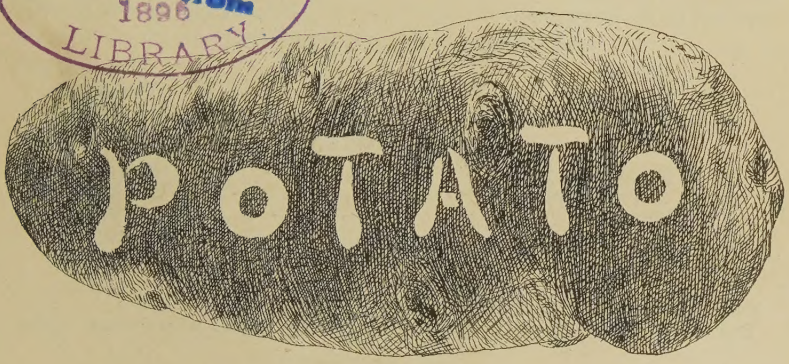
Bulletin 113. **February, 1896.**

Cornell University Agricultural Experiment Station,

ITHACA, N. Y.

HORTICULTURAL DIVISION.

DISEASES OF THE



U.S. GEOLOGICAL SURVEY
EXCHANGED
1896 from
LIBRARY

By E. G. LODEMAN.

IMPERIAL BUREAU
19 FEB. 1925
OF MYCOLOGY

PUBLISHED BY THE UNIVERSITY,
ITHACA, N. Y.
1896.

ORGANIZATION.

BOARD OF CONTROL:

THE TRUSTEES OF THE UNIVERSITY.

STATION COUNCIL.

President, JACOB GOULD SCHURMAN.

Hon. A. D. WHITE,	Trustee of the University.
Professor I. P. ROBERTS,	President State Agricultural Society.
Professor I. P. ROBERTS,	Agriculture.
Professor G. C. CALDWELL,	Chemistry.
Professor JAMES LAW,	Veterinary Science.
Professor A. N. PRENTISS,	Botany.
Professor J. H. COMSTOCK,	Entomology.
Professor L. H. BAILEY,	Horticulture.
Professor H. H. WING,	Dairy Husbandry.
Professor G. F. ATKINSON,	Cryptogamic Botany.

OFFICERS OF THE STATION.

I. P. ROBERTS,	Director.
E. L. WILLIAMS,	Treasurer.
H. W. SMITH,	Clerk.

ASSISTANTS.

M. V. SLINGERLAND,	Entomology.
G. W. CAVANAUGH,	Chemistry.
E. G. LODEMAN,	Horticulture.
L. A. CLINTON,	Agriculture.
E. J. DURAND,	Cryptogamic Botany.

Office of the Director, 20 Morrill Hall.
The regular bulletins of the Station are sent free to all who request them.

BULLETINS OF 1896.

106. Revised Opinions of the Japanese Plum.
107. Wireworms and The Bud Moth.
108. The Pear Psylla and The New York Plum Scale.
109. Geological History of the Chautauqua Grape Belt.
110. Extension Work in Horticulture.
111. Sweet Peas.
112. The 1895 Chrysanthemums.
113. Diseases of the Potato.

CORNELL UNIVERSITY, ITHACA, N. Y., Feb. 20, 1896.

HONORABLE COMMISSIONER, OF AGRICULTURE, ALBANY.

Sir:—For a number of years the farmers of western New York have been asking for light upon the insidious and serious diseases of the potato crop. A special effort has been made during the past season to study these troubles, and although the season was unusually dry and therefore not very productive of some diseases, the results of the investigations seem to be so useful that they are submitted for publication and distribution under Chapter 230 of the Laws of 1895. L. H. BAILEY.

SYNOPSIS.

Part I. Fungi. Pages 249 to 273.
- A. Descriptions of the fungous diseases, 249 to 264.
  - 1. Potato rot, late blight, or downy mildew, 249.
  - 2. Early blight, or leaf-blight, 254.
  - 3. Potato scab, 261.
- B. Treatments of the fungous diseases, 264 to 274.
  - 1. Potato rot or late blight, 264.
  - 2. Early blight, 265.
  - 3. Potato scab, 271.

Part II. Insects, 274 to 277.
- 1. Potato beetle, 274.
- 2. Flea-beetles, 275.

Part III. Machinery for spraying potatoes, 277 to 280.

Summary, 281.

"The most easy way to scourge the land, and force it to yield speedy returns, was by growing crops of potatoes, which are largely productive, but at the same time specially exhaustive of the mineral wealth of the soil. An average crop of potatoes robs the soil of the seed constituents of between three and four average crops of wheat. The tenants were too poor, and if they had been rich had no inducement, by the tenure of their land, to restore to the soil, through adequate manuring, the heavy demands which had been made on its fertility. At the time of the famine in 1846, nearly one-fourth of the land under crops was devoted to potatoes. And even now, out of every 100 acres devoted to green crops in Ireland, 71 are still given to potatoes—a proportion nearly three times greater than that in Scotland, and six times greater than that of England. * * * * * *

"The striking deterioration of the potato produce in Ireland deserves much more attention than it has received, but can only be slightly alluded to in the present essay. From 1601, when Raleigh introduced it into Ireland, the crop grew steadily in favor with the Irish peasantry until 1845, in which year the largest amount of acreage was devoted to it, and fine crops of six and seven tons to the acre were habitually and persistently attained. The famine came, and, as Irish agriculturists assert, the nature of the potato was altered by the disease of 1846, and its productive power was lessened; at least this is given as the explanation of its present low position among Irish crops. It is no longer the potato which is the farmer's chief source of profit in Ireland." ("Recess Studies," edited by Sir Alexander Grant, pp. 250–251.)

"If, then, the loss to Ireland is called 3,500,000 £, we should be glad to know how much the total loss will have been when the destruction in England, Wales and Scotland, is taken into account. To place the latter at 1,500,000£, is no very extravagant assumption; and if so, this country has lost five millions of money by the Potato murrain." (*Gardeners' Chronicle*, 1846, p. 219.

"*Copper Smoke a Preventive of Potato Disease.*—In the district about Meath and Swansea, "wherever the copper smoke prevails," was the expression of an intelligent inhabitant with whom I fell into conversation, the potatoes are sound, and the same person informed me it was also the case last year. I can verify the fact so far as the present appearance of the crop, as seen from the mail-coach roof, can be considered a verification; but I state it with a view of inducing more particular inquiry into it. You are, I dare say, aware the district I speak of is crowded with copper smelting furnaces" (*Gardeners' Chronicle*, 1846, p. 582).

PART I. FUNGI.

A. DESCRIPTION OF FUNGOUS DISEASES.

1. POTATO ROT ; LATE BLIGHT ; DOWNY MILDEW (*Phytophthora infestans*, DeBary).—The fungus causing the common potato rot is an old offender. It was undoubtedly introduced into Europe with some of the early importations of the potato, and has in certain years proved so destructive that famines have resulted from the entire loss of the potato crop. Such occurrences eventually lead to thorough study of the organism. As early as 1846, the fungus causing the trouble was very carefully described in an English publication,* and since that time other observers have given the disease much attention. It has spread to all regions in which potatoes are extensively grown, so that both scientists and farmers are very familiar with many of its characteristics.

The most interesting feature connected with the fungus is undoubtedly the wonderful energy which it exhibits, under favorable conditions, in the destruction of the potato plants. It sometimes spreads with such rapidity that a crop may be ruined in one or two days ; and unfavorable conditions, or the total destruction of the plants, formerly appeared to be the only effectual agents in preventing or checking the spread of the dreaded disease. This rapid decay of both the foliage and tubers is perhaps the most distinctive of those characters which are commonly brought forward for the identification of the disease. It is almost invariably accompanied by a strong, disagreeable odor which is easily recognized by all who have once experienced it. When large fields have been attacked, the smell is particularly strong ; it then arises entirely from the foliage, and is not produced by the tubers.

The conditions which favor such rapid decay are, as a rule, not generally present throughout this state. The fungus makes its most rapid growth in a temperature of about 70° F. when much moisture is present in the atmosphere. Cloudy days, with occa-

* Rev. M. J. Berkeley, *Journal of the Royal Horticultural Society*, Vol. I.

sional showers, and a close damp air are especially favorable to its growth; and if such periods occur during August and September, the disease may appear at any time. But, on the contrary, if the season is dry and hot the fungus is unable to develop, and little or no injury of this nature can appear. It is for this reason that the potato rot is not a regular visitor in most parts of the state, but is more generally confined to certain localities. These are found in the more northern potato districts, in the regions near the sea coast, and in some parts which have a high altitude. In such places the fungus may develop regularly every year, and the severity of the attack will be modified chiefly by abnormal atmospheric conditions.

The fungus causing the late blight of potatoes passes the winter in two forms. The mycelium, or vegetative portion of the parasite, may retain its vitality until the following spring, when growth may again begin and further attacks of the fungus take place. These are followed perhaps by less serious results than those which result from the other form. This second method of surviving the winter is effected by means of a small fruiting body known as an oospore. It is surrounded by a comparatively hard covering and is able to resist considerable extremes of temperature and moisture. The spores are produced in the fall within the tissues of the potato plant, and here they remain until the following spring or summer. By the gradual decay of the surrounding tissues these spores become liberated and when dry may easily be spread over wide areas by means of winds and other natural agencies. Those which eventually rest upon potato foliage soon germinate under proper conditions, and reproduce the fungus at the new point of infection. Here the development of the parasite takes place so fast that in a very short time such places become centers from which the disease is rapidly disseminated.

The manner in which the germ tube of a spore penetrates the tissues is interesting. It is now generally believed that the ends of the tube secrete a ferment which has the power of dissolving the walls of the cells comprising the outer layer of leaf tissue. When such an opening has been made, the small thread of the parasite enters and it then rapidly extends to other cells, and soon

the entire destruction of the leaf may be accomplished. A stoma, or breathing pore may also serve as a point of entrance.

The rapidity with which the fungus advances within the leaf tissues depends very largely upon external conditions, and the appearances of the affected parts is also modified to a very considerable extent. Unfavorable conditions frequently render the identification of the parasite a difficult matter without the aid of a glass, but under such circumstances the disease may be fairly widespread and still cause little injury. In serious attacks, however, many characteristic symptoms may be easily recognized.

The colored plate represents a leaf which has been entered in several places by the fungus causing late blight, or potato rot. The growth of the parasite has been rapid, and the illustration may be considered as a typical example in which the normal development of the disease was taken place. The following points should be noted:

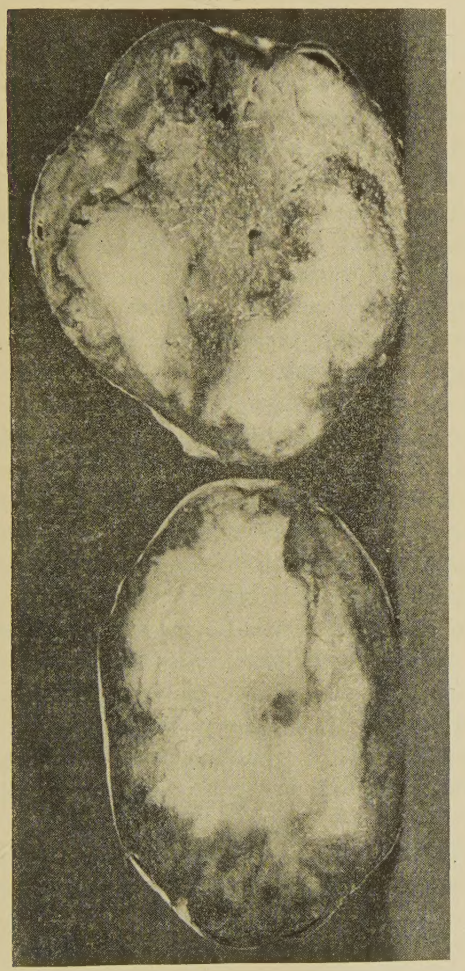
The diseased areas are of considerable extent, and possess a rich brown color. They may be situated in any part of the leaf, but the edges appear to suffer more from new infection than the more central portions of the leaflets. This is probably due to the fact that in case of rains these portions remain moist for a longer period than the center, since the water drains to the lower parts of the leaflets, and collects there in the form of drops of greater or less size. It is to be expected that under such conditions a fungus could gain an entrance more easily than in drier places. The decayed portions are inclined to droop; this is especially true in cases of rapid invasions, for at such times the parts do not dry so fast as the parasite advances The rapid decay also prevents the edges of the leaflets from curling, although this takes place when the air becomes warm and dry.

The distribution of colors over the affected leaf is very suggestive. Under normal conditions, the unaffected parts retain a deep green color, while the diseased area may be yellowish-brown, dark brown, or nearly black. But whatever the color, each area is sharply outlined. There is no gradual merging of one into the other, but a distinct change of color marks the progress of the disease. Occasionally another peculiarity may be noticed. If the leaves are closely examined it will be found that

the green and the brown areas are not directly in contact with each other; they are separated by a narrow strip in which the green has been destroyed, and the brown has not yet appeared. It consists of a colorless or at most a very pale yellow line in which the growth of the fungus is probably very active. But during periods which are unfavorable to the development of the parasite this line cannot be discerned, and the green and brown tissues are apparently in contact. Under such circumstances the identification of the disease without the aid of a microscope is an exceedingly difficult matter. Let us suppose that the fungus has succeeded in gaining an entrance, and that it has advanced a limited distance in the leaf tissues. If at this time the weather should turn dry and hot, the development of the parasites would be checked, and the result would be the formation of a small brown spot or area perhaps near the edge of the leaflet, and if several such spots exist the injury might be ascribed, without careful examination, to what is commonly knows as the early blight fungus.

The name "downy mildew" has been given to the potato rot disease from the fact that there appears, under favorable circumstances, a downy or mouldy growth upon the under surface of the leaves. This is white in color and may be of considerable density. The upper surface of the foliage does not show it, but whenever this frost-like growth appears on the under side, it is almost certain that the potato rot fungus is present, especially if the other conditions mentioned above are also present. This external growth consists of spores and of the parts bearing them. The spores, or conidia, mature very quickly, and have the power of immediately propagating the fungus. They are small and light, and may be carried long distances by winds. It is largely owing to these bodies that the progress of this potato disease is so rapid. They are produced in countless numbers and are very energetic in attacking healthy tissue. It appears to be very probable, also, that these conidia, or summer spores, are the cause of the rotting of the tubers. After maturing upon the leaf, some fall to the ground and by means of water and other mechanical agents they are brought in contact with the tubers growing underneath the surface of the soil. Here they germinate and

effect an entrance in the same manner as occurs above ground. The color of the affected parts also changes, a brown, dry rot taking the place of the normal white color (see Fig. 98). The more slowly the tubers decay, the less is the amount of moisture present; the contrary is also true. The decay does not take place in a uniform manner, but its progress varies in different tubers. In some it is mostly the parts near the surface that are affected, while in others the disease may advance rapidly towards the center of the tuber, causing the exterior to show a much smaller amount of disease than is actually present. The discoloration, however, generally presents a uniform appearance. Although it is by no means impossible for the mycelium to reach the tubers from the leaves by means of the stems, still it is the generally accepted opinion that infection does not take place in this manner. This belief was held many years ago, for in some of the earlier writings recommendations may be found in which very high hilling



98 — *Potato tubers affected with dry rot.* (*Phytophthora infestans.*)

is advocated so that the spores may be washed past the tubers and away from them, and not through the soil directly to them.

There is still another feature of the late blight which it is well to bear in mind. The disease generally appears during August and September, although earlier and later attacks are not very rare. Coming so late in the season, all the earlier varieties are comparatively free from attack, but the later ones are especially subject to the disease. This, however, is not necessarily due to the foliage of such varieties being more susceptible, but rather to the habits of the fungus. I have not observed that the age of the potato plants has a marked influence upon the spread of the disease; nor that the young foliage of the plants is less subject to the disease. It appears as if the parasite is able to thrive upon all potato foliage which is in a healthy condition at the time of the germination of the spores, and that old and young foliage or plants suffer practically to an equal extent. This matter is here empasized because it will be considered again in connection with the early blight of potatoes.

2. EARLY BLIGHT; LEAF-BLIGHT (*Macrosporium Solani*, E. & M.).—It is only within the past five or six years that the early blight of potatoes has been recognized by scientists and farmers as a distinct disease.* The trouble has been known during a longer period, and its general character fairly well understood. But the attention which in former years was given to the potato rot fungus caused this second disease to be overlooked, or at least to be regarded as perhaps a peculiar condition resulting from the attacks of late blight, or from certain conditions unfavorable to the growth of the potato plant. But since 1891 the fact has been clearly established that two distinct evils have preyed upon potato foliage, and since that time the second trouble, or, as it has been popularly called, the "early blight," has received considerable study.

The one character which was probably the most valuable in distinguishing the two diseases is the fact that plants having the

* For bibliographies of the earlier contributions concerning the early blight of potatoes, see Jones, *6th Ann. Rept. Vt. Agric Exp. Sta.* 1892, 66 *et seq.* Also Sturgis, *18th Ann. Rept. Conn. Agric. Exp. Sta.* 1894, 127 *et seq.*

early blight do not necessarily have rotten tubers, but on the contrary these are almost invariably perfectly sound, although small. The slow progress of the disease, and the peculiar discoloration and shriveling of the plants also made it apparent that there were two distinct diseases affecting the crop.

But the real cause of this trouble has not been found with equal readiness and certainty as was the case with the potato rot. Although at first it appeared as if the entire trouble could be laid at the door of the fungus *Macrosporium Solani*, yet later investigations have shown that the matter is not so simple as at first appeared. It is true that this fungus is almost invariably found in plants affected by this blight, and that the life of the plants is shortened perhaps to a considerabls extent by the fungus, yet it may be doubted whether the whole trouble should be ascribed to the one organism. But, before entering into detailed discussion concerning the cause of the early blight of potatoes, it may be well to define as clearly as possible the trouble which is generally designated by this term.

Upon referring to the plate it will be seen that the leaf upon the right differs considerably from the one which has thus far been considered. This illustration also was made from a typical leaf in order that the more essential features of the trouble might be the more clearly brought out. It will of course be understood that many variations occur, and that these are so great that frequently it is impossible to distinguish with the naked eye whether the phytophthora or the macrosporium is present Such cases are by no means rare, and I have seen a single leaflet suffering from the attacks of both fungi, as was proved by cultures, yet the two diseased areas were practically indistinguishable. Nevertheless, the following characters will be of assistance in determining which of the two fungi is responsible for the trouble.

Perhaps the most striking differences between the two leaves lie in the size, form, and position of the diseased areas. In the leaflets affected with the early blight, it will be seen that these areas are small as a rule, and that they are almost circular in outline except where several have coalesced, in which case the entire area is of irregular outline ; but all inequalities have rounded outlines. It appears as if infection occurred at a great number of points,

instead of in a few as shown in the other figure. And it is also interesting to notice that these many points of infection are, with but comparatively very few exceptions, placed along the outer edges or periphery of the leaflets. Although the same is to a certain extent also true with the other disease, still the fungus causing the potato rot does not confine itself nearly so persistently to the edges, but as soon as it is established it extends rapidly to all the softer tissues of the leaflets regardless of whether these are in one part of the leaflet or in another. It may also be stated of the early blight that frequently the leaf tissue situated along the larger veins succumbs to the disease more slowly than do those portions which are further removed from the veins.

If these diseased areas are very carefully examined, it will be found that it is a very common occurrence to find numbers of slight elevations or ridges arranged in circles about a common center. These may vary slightly in color, but they are perhaps most noticeable on account of their apparent elevation. Since such ridges are absent, so far as my observations go, in areas affected by the late blight, their presence is of considerable value in determining the character of the disease, the more so since the general color of the parts destroyed is very similar in the different cases.

When the colors of the green and apparently unaffected tissues in the figures are compared, another marked difference will instantly appear. The leaf affected with the late blight shows sound healthy tissue up to the region penetrated by the parasite. The leaflets appear to suffer only in those parts actually invaded by the mycelial threads of the fungus. Yet what is the meaning of the yellow color which pervades almost all parts of the other leaf? No parasite appears to have reached these portions, and yet they are manifestly unhealthy. Two explanations might be advanced; first, that the presence of the fungus has an injurious action extending beyond the parts in which it is growing, a supposition which may be said to have but very little support; and second, that the yellow color is due to a natural weakening or maturing of the plant, this in turn being brought about by untoward circumstances, or by age. This point will be touched upon more fully under the causes of the early blight.

In the illustration, the edges of the leaflets are shown as having

curled to a very marked degree. Such curling is not necessarily an indication of early blight, since whenever the leaf tissue dies, expecially at the outer extremities of the leaflets, the tendency seems to be for the leaf to roll upon itself as shown in the figure. Yet this character possesses a certain significance. In order that a leaflet should assume the position of those here represented, it is necessary that the death of the tissue shall occur more or less slowly, and that the change shall take place from the outer portions toward the center. As already stated, such conditions may or may not appear during an invasion of the late blight, and for this reason the curling of leaflets affected by early blight is of considerable value in identifying the present disease.

In addition to the characters above mentioned, there are several other factors which appear to be clearly connected with the early blight of potatoes. As the popular name of the disease implies, its appearance may be expected earlier in the year than the late blight ; but from this it does not follow that later attacks may not take place as well. The growth of the fungus does not seem to depend so much upon the season, as it does upon the condition of the plants exposed to infection. The writer has occasionally seen potatoes of the same variety growing side by side, but which were planted at different times, that were unequally affected by disease. The earlier plantings invariably showed much more injury than the later ones. In some cases the difference was so marked that it would scarcely be exaggerating to say that the younger plants were entirely free from disease, while the older plants, or those first set out, had lost about 50 per cent of their foliage area. Other modifying conditions were sought, but no other conclusions could be drawn than that in these cases at least, the entrance of the fungus depended upon the plants having reached a certain age.

A similar circumstance has frequently been noted in various parts of the state, with this difference, however, that the plants growing side by side were not of the same varieties. The effect was especially marked when late and early varieties were grown in the same field. The earlier the potato the sooner did it show the effects of disease, the later varieties remaining free for a long time ; or in case of late plantings, the foliage may have escaped

the trouble to a marked extent. A large number of fields have been examined with these points in mind, and such observations have lead to the conclusion that young, vigorously growing plants are practically free from the disease, while those which have almost completed their growth of foliage, and are rapidly forming tubers, are much more subject to attack.

The time of the appearance of early blight may therefore depend upon questions of plant physiology fully as much as upon the season, or even more so. Since fully developed plants, regardless of variety, are more subject to disease than the younger and more vigorously growing ones, it would seem reasonable to conclude that conditions which would cause the plants to ripen prematurely, or that will check the normal growth, will at the same time favor the appearance of the early blight. Facts tend to support this view of the case.

It has been my observation that plants grown upon dry soils, those which are naturally warm and "quick," are more subject to the disease than those grown in moister places in the same field. That is, the early blight appeared first upon the high and dry knolls, and it is here also that the tubers mature the earliest. Seasons of protracted drought, therefore, might be supposed to have a similar effect, and the testimony of all observers bears out the supposition. It is in dry weather that the early blight progresses most rapidly, the late blight requiring a moist atmosphere for its best development. The falling of rain upon a field in which the tops are gradually yielding to the invasion of early blight has a tendency to freshen the plants and apparently to give them a new lease of life. Water seems to be the one thing most needed. Upon lower land the conditions are different, and as a rule such lands suffer less from drought, and the potato crops less from the early blight.

A curious exception to the above may here be noted. I have many times seen potatoes growing under trees in dry fields where all the potato plants were suffering severely from the early blight except those protected by the foliage of the trees. As a rule the thicker the foliage upon the tree, and the nearer the branches came to the ground, the less was the injury from blight to the potatoes below. This may be explained by supposing that the

spores of the fungus (assuming it to be the sole exciting cause of the trouble) are unable to reach the plants, a scarcely warrantable belief; or, that the spores which do succeed in reaching the potato foliage are unable to germinate on account of lack of moisture. There are several arguments forming the second supposition, for with the exception of the more or less complete absence of direct sunlight and rainfall, the plants growing under the trees are in practically the same condition as those growing within the area occupied by the feeding roots of the tree. They have about the same amounts of soil moisture and of heat, and they also suffer to nearly the same extent from injury by insects. But they escape the moisture of light showers, and they are also free from dew. It appears probable, therefore, that the secret of their immunity from disease lies in this fact.

Although the character of the season exerts a great influence upon the prevalence of early blight, it is not the only great factor which has the power of seriously reducing the vitality of potato plants. A second agent is a small organism which often appears in countless numbers. It is generally known as the flea-beetle, on account of its quick movements when disturbed. The injury done to the foliage by these little beetles is greater than was formerly supposed. They feed upon the tissues of the leaves, taking out small amounts at different points. Very frequently sufficient material is removed to cause the formation of small holes which extend through the leaf. The diameters of these holes are scarcely larger than that of a pin, yet a leaf is often riddled to such an extent that its vitality is seriously affected. In the plate the leaf affected with early blight shows the results of the work of these insects, yet only the more serious part of the injury could be represented. If a fresh leaf is closely examined it will be found that there are many places in which the beetles have begun to feed, yet when the epidermis of the leaf has been penetrated, and only a few of the cells underneath have been destroyed, the insect changed its base of operations, leaving scarcely a trace to bear witness of its presence. It is true that often when a leaf has been partially pierced, the color of the spot becomes much lighter, but the intensity of the color depends very largely upon the amount of injury done, and in certain cases the change can scarcely be distinguished.

The results of such repeated attacks of the flea-beetle cannot be otherwise than disastrous to potato foliage, and I have heard several growers maintain that the work of the flea-beetle is more to be dreaded than that of any other organism which injures the plants. In localities where these beetles are numerous, such statements do not exaggerate the matter, for the vigor of the entire plant is frequently much reduced by these insects.

From what has already been said regarding the physiological effect of other injurious influences, it would seem very probable that the work of the flea-beetle may also be considered as being a means of reducing potato plants to a condition which renders the development of the early blight fungus possible. This supposition is supported by facts. If a potato leaf is examined when the first traces of early blight appear, it will probably be found that the first browning of the tissue occurs about the edges of holes made by flea-beetles, or in places in which the tissues have been but partially injured. This is perhaps not always the case, but it has proved to be so in the vast majority of the leaves which I have examined. A reddish-brown zone of varying width is formed about a central point (see plate) and this gradually enlarges until other similar discolorations are met, and the gradual uniting of several of these originally distinct areas, causes the more or less continuous destruction of the tissue at the edges of the leaflets. When the discolorations start nearer the center of the leaf, they generally remain isolated for a longer period.

The later stages of the disease are well known to potato growers. The entire leaves gradually assume the brown and shrivelled appearance, and the stems in turn become yellow, dry, and brown, so that nothing remains of a formerly green and flourishing plant except a few withered remnants of foliage, and a number of small, partially developed tubers. These do not rot, but owing to the death of the tops they remain small from want of nourishment.

It follows from the preceding remarks on the early blight, that the fungus which is commonly held responsible for the injury is not a true parasite ; that is, it will not attack healthy tissue, but only succeeds in obtaining a foothold after the potato foliage has become weakened by age, by unfavorable climatic conditions, or by mechanical injuries, chief among which is probably the flea-

Drawn and Colored from Nature for
Cornell University Experiment Station.

COLORITYPE CO., N. Y., FOR
J. HORACE McFARLAND CO., HARRISBURG, PA.

POTATO-BLIGHT

beetle. This places the most effective lines of treatment upon a different basis from that generally followed with other fungous diseases; instead of preventing the entrance of the organism by means of protective substances, the constitution of the plant itself is to be strengthened, and the removal of as many injurious influences as possible is desired.

There appears to exist another trouble which is generally confounded with the early blight; in fact it is very difficult to distinguish the two without the aid of laboratory methods. This disease, which is entirely of a physiological nature, has been thoroughly discussed by Sturgis.* It has been found only to a limited extent in New York, for almost invariably cultures made from affected leaves freely developed the early blight fungus. According to Sturgis the same conditions which produce the early blight also bring about the death of certain parts of the leaf tissue, in a manner almost identical with that of the macrosporium. He says: "Both classes of injury appeared in connection with the marks of the flea beetle, both were exhibited as brown spots and blotches marked with concentric rings; but in specimens characterized by the presence of the fungus, the spots were more sharply defined and darker in color. This difference was sufficiently marked to enable a close observer to distinguish either one in the field after a little practice, but a comparison between the two produced the impression that both classes of injury might have been caused by the same agency, and that the slight difference in appearance might be due to the fact that in the one case a fungus had occupied the injured tissue, and in the other had not done so."

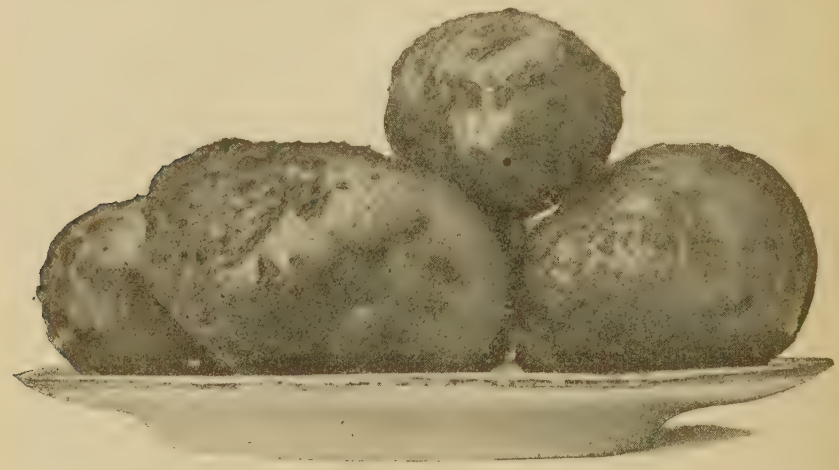
It seems, therefore, that the causes which lead to the appearance of these two diseases are the same, and the same lines of treatment are consequently indicated.

3. POTATO SCAB (*Oospora scabies*, Thaxter).—This disease is one which is well known to potato growers. Figure 99 represents affected tubers. The uneven, warty growths upon the surface of the potatoes are composed of material produced by the tubers in consequence of the irritation of parasitic organisms which live upon the substance of the potatoes. Under favor-

Ann. Rept. Conn. Agric. Exp. Sta. 1894, 127–134.

able circumstances these injuries are very extensive, for the entire surface of the tuber may be affected, and although the affected parts do not always penetrate very deeply, the blemished appearance of the tubers and the actual loss of material may become very serious.

The causes of potato scab have been discovered only within recent years. The disease was carefully studied in 1889–90 by H. L. Bolley, who was then assistant botanist of the Indiana Experiment Station. The results of his work appeared in *Agricultural Science*, 1890, Nos. 9 and 10.* He ascribed the



99.—*Scab on potatoes.*

cause of the trouble to a certain bacterium which had the power of injuring tubers while they were in active growth, but later caused little injury. The injuries produced by the microbe are generally rather shallow, not extending deeply into the tissues of the tubers.

Later in the year 1890 Dr. R. Thaxter of the Connecticut Experiment Station read a paper upon potato scab in which it was stated that potato scab is due to the work of a fungus.†

*See also *N. Dak. Agric. Exp. Sta.* 1891, Dec. Bull. 4, which contains a record of Bolley's work and a full bibliography of the subject.

†The paper was read Nov. 12, 1890, at Champaign, Ill., before a meeting of the Association of Agricultural Colleges and Experiment Stations. See also a full account in the *Ann. Rept. Conn. Agric. Exp. Station.* 1890, pp. 80–95.

More recent investigations have verified the work of Thaxter, and it is now the generally accepted belief that practically all the injury which is commonly known as scab is due to a fungus (*Oospora scabies*, Thax.). This frequently enters deeply into the potato, especially if the infection occurs early in the season when the tubers are small. When older tubers become affected, the injury generally assumes the form of a corky crust upon the surface.

The conditions which favor the growth of the potato scab fungus are dampness and an alkaline condition of the soil. It is a common experience that scab is more prevalent in soils rich in organic matter, and abundance of air and moisture allow a more vigorous growth of the parasite to take place.

The fact that an alkaline soil causes more severe attacks of potato scab has an important practical bearing. A soil may be made alkaline in a number of ways, especially by the addition of certain fertilizers. Lime has a very strong tendency in this direction, and stable manure exerts a similar influence. This fact has undoubtedly given rise to the popular belief that stable manure will increase the amount of scab upon potatoes. The appearance of the fungus may be favored merely by the alkaline condition of the soil, or it may actually be applied to soil which is free from the disease, and thus an entire field be infected by the fertilizer. If both the soil and the manure are free from disease, no scab will appear, unless it exists upon the tubers used for seed. All fertilizers which have a tendency to produce an acid condition of the soil may check the growth of the fungus, and by the proper selection of fertilizing material sometimes a very marked effect may be produced upon the crop.*

During 1894, a third cause for the injury generally known as scab was advanced by A. D. Hopkins, entomologist of the West Virginia Experiment Station. The first account of his investigation of this diseasewas read before the West Virginia State Horticultural Society April 6.† In this paper it was said that the larvæ of one

*An excellent account of the effect of various chemicals and manures upon the amount of scab upon potato tubers has been published by Wheeler and Tucker in Bull. 23, of the *R. I. Agric. Exp. Sta.* Oct. 1895.

†See Special Bull. 2. *W. Va. Agric. Exp. Sta.* pp. 97–111. Also, Proceedings of the Washington Entomological Society, May 3, 1894; *Insect Life*, vii. p. 147.

or two species of insects (*Epidapus scabies*, Hopkins, and *Sciara* sp.) disfigure potatoes in a manner very similar to that of the scab fungus. In the more northern states, however, these insects do not appear to be so troublesome, and the methods of treatment recommended for the destruction of the fungus are generally very effective in controlling the disease.

B. TREATMENT OF FUNGOUS DISEASES.

1. POTATO ROT OR LATE BLIGHT.—Bordeaux mixture is the sovereign remedy for the rot or late blight. It was first successfully used by the French in 1886 and since that time innumerable experiments have been made with this fungicide in checking the trouble. Success has followed whenever the applications have been properly made, and it is no longer a question whether the mixture will prevent the blight; it is now entirely a matter of judgment and skill on the part of the grower. If the Bordeaux mixture is properly made*, and thoroughly applied at the right time, scarcely a decayed tuber should appear in the field. It is impossible to state when the first applications should be made, nor how many times the plants should be treated, for the conditions vary so much in different localities. As a rule it is unnecessary to begin spraying before the middle of July, and the first of August will prove none too late in the majority of cases. The character of the season, and the prevalence of the disease in former years must serve as guides as to the best time to begin spraying. In certain localities the late blight appears with considerable regularity, and in such cases it is well to spray about ten days before the period in which the trouble is generally first noticed.

Later applications may be made at intervals of one to three weeks, depending upon the weather. Even in years favorable to blight, three applications should be sufficient to protect the plants

* A good mixture for use upon potatoes may be prepared by dissolving 6 pounds copper sulphate in about 12 gallons of water; slake 4 pounds quicklime and add to the copper sulphate solution. Dilute to 40 gallons. If the ferocyanide of potassium test is employed, put in about one-fourth more lime than the test solution shows to be necessary.

almost perfectly. The foliage should be thoroughly covered from above, and if the spray may be conveniently applied from below also, so much the better. A fine and abundant spray will be found most satisfactory (see page 277 for report upon spraying machinery).

2. EARLY BLIGHT.—The successful treatment of the early blight is by no means an easy matter, as appeared in the discussion of its probable causes. It was shown that the early blight does not appear until the period of active growth is passed, or until the plants have become weakened by some mechanical agency.

The first step towards checking the trouble, therefore, is to maintain the plants in as vigorous condition as possible. Proper fertilization, abundant cultivation, and close attention to the welfare of the plants become matters of prime importance. The selection of suitable land in favorable localities, and its thorough preparation will also prove of material benefit. This disease is an excellent example of the theory that disease in plants is not the prime cause of injury, but rather only an indication or symptom of weakness which existed before the injurious organism could gain an entrance, and which in fact must exist before such an entrance can be effected. The idea, however, does not apply so aptly to all cases of the disease.

The mechanical injuries to potato vines are mostly brought about by insects, and chief among these is the flea-beetle. The methods of treating this pest will be found on page 275.

The bulk of the injury done by the early blight has been ascribed to a fungus (*Macrosporium Solani*) which unduly hastens the destruction of plants that are already on the down-hill side of life. The fungus is widespread and is undoubtedly responsible for much of the injury done to potato crops.

During the summer of 1895 the writer endeavored to control the early blight by means of thorough application of the Bordeaux mixture. Four plots were selected for the work, I and II being upon the University farm where Professor Roberts kindly allowed me the use of certain portions of the potato field, and materially assisted in carrying on the work; plots III and IV were upon the farm of H. R. McNair, Dansville, N. Y. By distributing the

plots in this manner it was hoped that more accurate and convincing results might be obtained.

Plot I.—The land selected for the experiment was divided into four sections, each covering an area of a little more than three square rods. Burbank potatoes were planted May 16 in rows 3¼ feet apart, the pieces being put in at intervals of 14 inches. At this rate it was estimated that about 10 bushels of seed would be used per acre.

Notes taken July 5 show that the plants were growing vigorously, and were scarcely troubled by flea-beetle. The first application was made at this time, the four sections receiving the following treatments: 1. Bordeaux mixture made May 18, it having been allowed to stand since that time and receiving only an occasional stirring; 2. Bordeaux mixture freshly prepared;* 3. no treatment; 4. copper chloride mixture.† The materials were applied with a knapsack pump and Vermorel nozzle. It was found that the application could be made very satisfactorily in this manner with the exception of section 1, which received the old Bordeaux mixture. The sediment settled so fast that it was mostly applied before one-half of the required amount of liquid had been used, in spite of repeated shaking of the tank by the operator. This necessitated a second treatment immediately after the first, the work being started at the opposite end of the section.

On July 23 the above treatments were repeated with the exception that section 1 received but one application, the distribution being still more uneven than the first time. There was some indication of early blight, yet not enough to distinguish whether the treatments had been of value.

August 28, however, showed a marked difference in the appearance of the sections. The third, which was untreated, had fully 50 per cent of its leaves badly affected; the first was as bad as

---

* The Bordeaux mixture was made according to the "Normal" formula; copper sulphate, 6 pounds; quicklime, 4 pounds; water, 45 gallons. This mixture contains copper sulphate at the rate of 1.6 per cent of the weight of water used.

† This mixture was made by dissolving 3 ounces copper chloride in 24 gallons of water, and then to this solution was added 6 ounces of slaked quicklime.

the check where little of the sediment had been applied, but where the spraying had commenced, and consequently upon that part which received most of the solid contents of the knapsack pump, the foliage was much better, scarcely 10 per cent of the leaves showing serious injury. Section 2 also appeared very thrifty since the foliage averaged fully as well as the best parts of section 1. Section 4, the one which was treated with the copper chloride mixture, appeared to have fully 25 per cent of its leaves seriously attacked. Section 2 was again sprayed with fresh Bordeaux mixture, the other sections remaining untreated.

Other observations were made September 12. At this time the relative amounts of early blight appeared to be about the same as two weeks previous. The part of section 1 which had received most of the sediment was in as thrifty condition as section 2 which had received the extra treatment. From this it would seem that the last application made to section 2 was of minor importance. The vines at that time had practically completed their growth so that there was little new foliage exposed to the disease. The rainfall had also been slight, and the Bordeaux mixture could still be plainly seen upon all sections treated with it.

The potatoes were dug September 26. Since the sections varied somewhat in size, the yield of each has been estimated upon the proportionate yield per acre, this furnishing a more convenient basis for comparison. The result was as follows:

Section 1, Old Bordeaux mixture, 332 bushels per acre.
" 2, Fresh Bordeaux mixture, 350 bushels per acre.
" 3, No treatment, 284 bushels per acre.
" 4, Copper chloride mixture, 297 bushels per acre.

The apparent gains from the treatments of the sections were accordingly, 1–48 bushels; 2–66 bushels; 4–13 bushels. The advantage derived from the copper chloride mixture is so slight that it promises little practical value. The results obtained with the Bordeaux mixture, however, are more encouraging, and seem to indicate that it may be possible to spray for the early blight, although the margin may at times be close.

To what extent these gains were due to the prevention of injury to the flea-beetle it is difficult to say. The vines which were most thoroughly sprayed with the Bordeaux mixture did not

escape the attacks of this insect, as could be seen by the many pits which remained as witnesses of its presence. Untreated plants suffered more severely, as they did also from the early blight. The probable action of the Bordeaux mixture thus appears to be two-fold. In the first place it prevents to a very considerable extent injury from the flea-beetle; in the second place it prevents the entrance of the macrosporium into tissues which have suffered from the work of the insect, and also protects those which are made susceptible to the disease in other ways. It is certain that the fungus was very abundant in the foliage of untreated plants, and it seemed probable that the value of the mixture was just as great in preventing injury from this source, as it was in protecting the leaves from the attacks of insects.

Plot II. This plot was also upon the University farm. It contained just one-third of an acre, and was planted to several varieties of potatoes, some of which were considerably earlier than others. The field was divided into two nearly equal parts, the line of division running across the rows so that each part should contain the same proportionate amount of each variety. One portion was sprayed with the Bordeaux mixture, the other part remaining untreated. Applications were made July 13 and August 12, fresh Bordeaux mixture being used each time.

At the time of the second spraying, a remarkable difference could be seen between the two parts. The untreated portion showed fully 50 per cent of badly blighted foliage, while that of the sprayed part scarcely exceeded 5 per cent. This difference was especially marked in case of the earlier varieties, and it could be distinguished a considerable distance from the field. The untreated vines perished earlier in the season, and when scarcely a vestige of green could be found in the check section, the other portion was still fairly green, at least the tops appeared to possess a decided ability to nourish the tubers which were depending upon them for support. At this time the very late varieties, such as the Orphan, were all of a deep green color, apparently unaffected either by flea-beetles or by blight. Their turn came later in the fall, although the difference was never so clearly defined as in the case of the earlier varieties.

These potatoes were dug during the last days of September, and yielded at the following rate:

Section 1. Fresh Bordeaux mixture, 311 bushels per acre.
" 2. No treatment, 272 " "

This represents a gain of 49 bushels per acre, a result apparently due more to the prevention of the macrosporiun than to the destruction of the flea-beetle, for the latter was not conspicuous by its absence. The fungus was very prevalent, and the vines appeared to succumb rapidly when it had once gained a foothold.

Plot III. The figures relating to the experiments in plots III and IV mere obtained from Mr. McNair, who very kindly looked after the work in such a thorough manner that the results are here published in full. The McNair farm is situated near the head of the famous Genesee Valley, upon the bottom lands. The potato rot is an occasional visitor, but during the summer and fall of 1895 practically no rot was discovered, as was also the case upon the University farm, so that the beneficial results of all applications must be due to the prevention of other troubles, these being commonly summed up in the term early blight.

Mr. McNair grew a number of acres of White Star potatoes, and in his field the plots and sections were laid out so that four rows extended from one end of the plantation to the other. Only the two central rows were considered when the yields were measured. The potatoes were planted May 28, and were sprayed with the Bordeaux mixture July 19 and August 5. This mixture was made of different strengths.

a. The most concentrated form contained 6 pounds copper sulphate, 4 pounds quick lime, and 40 gallons of water.

b. This mixture contained 5 pounds copper sulphate, with lime in the above proportions, in 40 gallons of water.

c. The amount of copper sulphate was reduced to 4.3 pounds in 40 gallons, with lime in proportion.

d. Only 3.5 pounds copper sulphate were used to 40 gallons, the amount of lime being likewise reduced.

Five sections were selected, each having four rows and containing 24 square rods. One section remained untreated, but the remainder were sprayed with the different mixtures. The work was done by an efficient power sprayer which Mr. McNair had

made. Vermorel nozzels were used, and very satisfactory work was done, although the amount of liquid applied might perhaps have been increased to advantage.

When the potatoes were dug in the fall the following yields were obtained, the figures again showing the proportionate amounts per acre:

Section 1, Untreated, 209 bushels.
" 2, Mixture *a*, 227 "
" 3, " *b*, 234 "
" 4, " *c*, 221 "
" 5, " *d*, 191 "

These figures are not altogether encouraging for the sprayer. Sections 2, 3, and 4 on the average yielded an increase of only 18.3 bushels per acre, while section 5 produced 18 bushels less than the untreated one. These figures appear to represent the actual gains, yet no apparent reason exists for the decreased yield of section 5. Probably local conditions of the soil exerted this influence.

Plot IV. This plot was situated in another part of the field. Only two sections were made, these being still larger than in the preceding experiment. The most concentrated Bordeaux mixture above mentioned was applied to one, the other remaining untreated. The plants were sprayed at the same time as in the preceding case, and the same machinery was used. When the crop was harvested it was found that

Section 1, untreated, yielded 252 bushels per acre.
" 2, Bordeaux mixture, yielded 298 bushels per acre.

In this plot, the gain was 46 bushels per acre. Apparently the conditions were exactly the same, and as this result corresponds fairly well with the results obtained in Ithaca it may be stated that spraying for the early blight is of advantage, and if the applications are properly made, the operation should be profitable.

In summing up the gains obtained by spraying with fresh Bordeaux mixture for the early blight, omitting section 5 in plot III in which an actual loss occurred, it is found that the average increase in the four plots is 44.8 bushels, by no means an insignificant amount. In order that such results may be obtained, it is essential that very thorough work shall be done, and that the operation shall take place at the proper time.

Mr. McNair also kindly furnished me with some interesting data regarding the value of having plants sufficiently thrifty to withstand early blight, a subject already discussed upon page 260. He found that in a certain portion of his field the addition of 10 loads of barnyard manure per acre produced an increased yield of 19 bushels. When there were also added 100 pounds of sulphate of potash, and 100 pounds of Carolina rock, and the plants were in addition well cultivated and sprayed, the actual increase in yield was 100 bushels per acre, as was shown by an adjoining plot.

The early blight, therefore, should be treated by growing vigorous plants, and by protecting the foliage against the work of insects and fungi by the use of the Bordeaux mixture.

The early blight may also be avoided to a certain extent by planting early varieties, as these frequently mature before the blight does much harm; and also by planting late, for in this case the plants will be in active growth during the season when the blight is most prevalent, and it has already been shown that such plants are practically free from the disease. During the fall, when the plants are maturing, there is less danger of attack.

3. POTATO SCAB.—The remedy proposed by Bolley* may be considered as almost a specific for this disease. His first recommendation was to soak the seed in a solution of corrosive sublimate for one and one-half hours. The solution was made by dissolving 2 ounces of the poison in 15 gallons of water. Potatoes treated in this manner are practically free from the scab fungus, as the latter is usually destroyed, unless the potatoes used for seed are very badly injured. In such cases it appears that some of the germs of the disease may escape and serve as sources of infection in the field. In order to overcome this defect, the use of stronger solutions have been recommended, or the immersion of the tubers during a longer time. Bolley's latest recommendation is to dissolve 10 ounces of corrosive sublimate in 60 gallons of water, and the general tendency among experimenters is to use stronger solutions than the ones first recommended. The period of immersion also varies from one and one-half to three hours. Probably the period of treatment may vary with the amount of scab upon the tubers, and with the depth to which the tissues are

*N. Dak. Agric. Exp. Sta. Bull. 4, p. 14.

diseased. The germinating power of potatoes is sometimes impaired if they are treated with the strong solutions for the long periods recommended. It is advisable therefore to get as clean seed as possible, but if the potatoes are scabby, to treat them with solutions whose strength increases with severity of the disease on the tuber, at the same time lengthening the period of immersion.

It has been my experience that it is fully as important to have clean land as it is to have clean seed. The fungus causing the trouble appeared upon potatoes which were grown from clean seed upon land that had not been used for this crop during five years, although two crops of beets had been grown upon it during this period. How long the disease may persist is not known, but it was sufficiently severe during the comparatively dry season of 1895 to obscure the results of several experiments designed to show the value of various treatments of Burbank potatoes for the destruction of the scab fungus. The soil selected is a moderately moist gravel loam.

Another portion of the field had not grown potatoes for eighteen years, and the land proved to be entirely free from the disease. The portion selected for the experiments is a comparatively dry gravel loam, in a high state of cultivation. The attempt was here made to lessen the disease by means of copper and brass shavings, these being mixed with the soil in the drills. No beneficial results from the treatment were observed, however, even when enormous quantities of the shavings were used. It was evident that too small an amount of the metals entered in solution to affect the growth of the scab fungus, although the spores of other fungi are unable to germinate in water which has passed through a copper pipe only a few feet in length.

An attempt to increase the amount of scab was, however, entirely successful. A small handful of air-slaked lime was scattered in the drills where the pieces of potato were planted, and when these potatoes were dug it was found that the number of scabby potatoes was more than twice as great as in the rows which received no treatment; the individual tubers were also more seriously affected. Air-slaked lime therefore appears to have a decidedly favorable influence upon the growth of the fungus.

An alkaline or an acid condition of the soil becomes a serious matter in certain potato growing regions. This question has been

very thoroughly studied at the Rhode Island experiment station* and several of the conclusions obtained are here given.

"Wood ashes (which like air slaked lime consists largely of calcium carbonate) pure calcium carbonate, calcium acetate, and calcium oxalate, promote the scab in a high degree.

"Calcium chloride injured the potato plants but entirely prevented scab, although an abundance of germs was probably introduced.

"Calcium sulphate (known as land plaster and gypsum) is the only form of lime employed which has not injured the growth of the crops, and which has at the same time failed to promote with certainty the development of the scab.

"Upon our acid soil, which has been partially neutralized by air-slaked lime, the use of ammonia sulphate has, under otherwise like circumstances, resulted in producing tubers less scabby than where the same amount of nitrogen in form of sodium nitrate was used.

"Common salt has reduced the percentage of scab.

"Sodium carbonate acts in the same way as calcium carbonate, though perhaps not in the same degree, and promotes decidedly the development of disease.

"Barnyard manure, owing to its alkalinity or the production of carbonate from it, has probably in and of itself increased the scab.

"Oxalic acid seems to have a tendency . . . to reduce the percentage of scab.

"By the use of ammonium sulphate and probably muriate and sulphate of potash, Kainit and common salt in connection with *dissolved* phosphate rock, dissolved bone, or dissolved bone black, soils which now tend to produce scabby tubers, would probably become less favorable to the disease. It is possible that a rational system of rotation of crops *which would include no beets or other root crops*, and perhaps no cabbages, would also help to alleviate the condition in such soils."

*Wheeler and Tucker. Bull. 33, pp. 58–79.

PART II. INSECTS.

1. POTATO BEETLE. (*Doryphora decemlineata*, Say).—This insect is too well known to require description. During the past twenty-five years it has been very generally destroyed by the use of Paris green, and in more recent years also by London purple. These poisons were at first applied in dry form, being mixed with flour, plaster, air slaked lime, and similar powders. The proportions of the ingredients varied greatly, one part of the poison being added to from one to fifty parts of the diluent. The mixture was then dusted upon the plants by means of perforated boxes, or bags made of coarse material. In recent years very effective machines have been invented for the purpose of making uniform applications of powders with great rapidity, and these have largely supplanted the older devices. The powder is driven forcibly from the machines by means of an air blast; when applied in this manner it is well to mix one part of poison with one to three parts of air-slaked lime. The lime makes the powder visible as it leaves the machine, and it also prevents injury from the poison; for these reasons it is probably the best diluent to use. One and one-half pounds of these arsenites per acre is sufficient for each application.

The more popular method of applying arsenites at present is to mix them with one hundred and fifty or two hundred gallons of water. An equal weight of quicklime should be added to the mixtures, first slaking the lime in water. This prevents the caustic action of the arsenites, and yet does not interfere with the machinery. When poisons are applied in water with proper machinery, rapid applications may be made at all hours of the day, and with but little regard to the weather.

Paris purple* is another form of arsenic which has been sold during a number of years for the destruction of potato beetles. It resembles London purple, but is of a deeper color and mixes with much greater difficulty with water. In our experiments it proved

*Chemical analysis of Paris purple showed it to contain 34.1 per cent arsenic trioxide, 40.7 per cent of this being soluble in water. It is sold by Sykes & Street, 85 Water street, New York.

effective when used at the rate of one ounce to four gallons of water.

Within the past few years another form of arsenic, known as English purple poison*, has been offered for sale in this country. The results of various trials of the poison upon potato foliage show that when used at the rate of one ounce to four gallons of water it is effectual in destroying the insects. But it also possesses the serious objection of mixing slowly with water.

2. FLEA-BEETLES.—The most serious insect enemy of potatoes is undoubtedly the flea-beetle. The insects are scarcely a tenth of an inch in length; they are nearly black in color, and the quickness of their movements has caused them to receive their popular name. There appear to be several broods each season, so their work is more or less continuous during the growing season.

Many remedies have been suggested for the destruction of this pest. Among them may be included the following: Paris green; London purple; decoction of tobacco; kerosene emulsion; air-slaked lime; land plaster; wood ashes; tobacco powder; Bordeaux mixture.

With the exception of the last named remedy, all the above appear to be without practical value for potatoes. I have tried Paris green, London purple, kerosene emulsion, tobacco powder and air-slaked lime with no apparent benefit; and as others have failed in obtaining satisfactory results with these as well as with all the others except the Bordeaux mixture, their use cannot be recommended.

The Bordeaux mixture, however, appears to be a promising remedy. Jones has tested the material very thoroughly and the following is his opinion of the value of his treatments.† "The actual number of holes per leaflet, from the unsprayed row was found upon counting to be 262, which from the sprayed row the average was but 12. . . . These results bear out completely the conclusions of last year, and justify the claims that the Bordeaux mixture is the best practical remedy known for the flea-beetle as

*The poison was introduced by Henry S. Ziegler, 400 N. Third street, Philadelphia, Pa. It contains 36.75 per cent arsenic trioxide, 14.58 per cent of which is soluble in water.

†*Ann. Rept. Vt. Agric. Exp. Sta.* 1894, 96.

it occurs upon potatoes." The leaves examined by Professor Jones appear to have been sprayed with the mixture June 16 and July 17, and the results obtained by him are decidedly encouraging. His work indicates that these early treatments are essential for obtaining the most thorough protection, but as applications of Paris green are generally made at this time for destroying potato beetles, very little extra work is required for treating the vines with the Bordeaux mixture also.

The results of my work during 1895 do not show such marked differences as those quoted above. The foliage of all the plants mentioned in the preceding pages was several times examined with particular regard to the work of the flea-beetle. The number of holes in the leaves was not counted, but the independent estimates of different observers practically agreed with those of the writer, and they may be considered as representing fairly well the amount of protection afforded by the Bordeaux mixture. Upon the university farm it was estimated that the amount of injury upon the sprayed foliage was from sixty to seventy per cent as much as upon untreated vines. The section which was treated with the old mixture showed less injury where the greatest amount of sediment was applied, and more at the other end where the mixture was much diluted.

The potato foliage on the farm of Mr. McNair was also protected, but to a less degree. His plants were treated the first time July 19. The foliage already showed considerable injury from the insect, but no blighting of the foliage was apparent. Five weeks later we estimated the amount of flea-beetle injury upon the section which received the most concentrated mixture to be about eighty five per cent of that upon untreated vines. In the other sections the difference was still less marked. It would seem that in order to derive the greatest benefit from the Bordeaux mixture in preventing the attacks of flea-beetles, the applications must be made during June and July, and a strong mixture should be used.

PART III. SPRAYING MACHINERY.

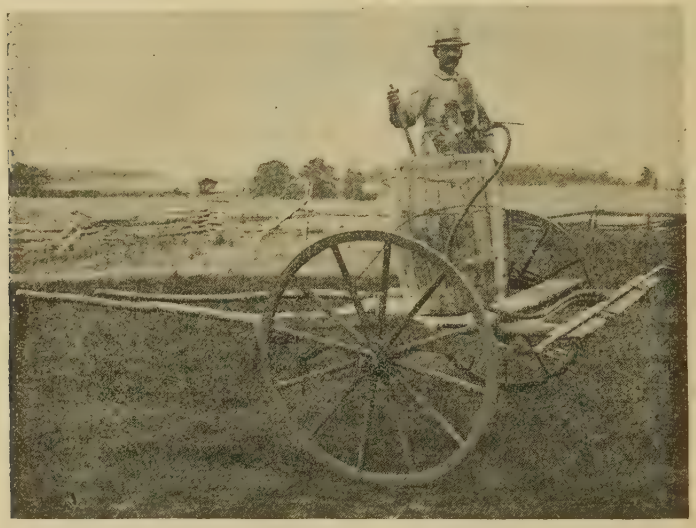
A trial of machinery suitable for the spraying of potatoes was made July 18 upon the farm of J. S. Coombs, Stafford, Genesee Co., N.Y. All manufacturers were invited to be present and to exhibit machines, for the field which Mr. Coombs kindly placed at their disposal was particularly well adapted for such a trial. The land was perfectly level, well cultivated, and the plants only about one-third grown. The farm is accessible from three railroads, and no more favorable conditions could have been desired. The circular letter addressed to the manufacturers stated that the normal Bordeaux mixture (see page 266) would be applied, as this would give them an opportunity to work their machines under actual field conditions.

Upon the appointed day, the following manufacturers were represented: Aspinwall Mfg. Co., Jackson, Mich.; Deming Co., Salem, O.; W. & B. Douglas, Middletown, Conn.; Excelsior Co., New Haven, Conn.; Leggett & Bro., 301 Pearl St., New York; F. E. Myers & Bro., Ashland, O.; Potter & Ware, Batavia, N. Y. (exhibited a machine made for their own use); Seth K. Samms, Byberry, Philadelphia, Pa.; J. R. Steitz, Cudahy, Wis.; Studebaker Mfg. Co., South Bend, Ind. The machines shown by these ten exhibitors were of very varied nature: small bucket pumps, barrel pumps, power sprayers, gravity sprayers, and powder guns were to be found among them. Twenty machines were exhibited, and most of them were tried in the field, each manufacturer having at his disposal an acre of land.

Before the field work was commenced, a committee of local potato growers was appointed; this committee was to judge of the merits of the various machines, considering them from the standpoint of practical growers. The men, selected by the local Grange, were as follows: J. G. Fargo, E. D. Rumsey, J. H. Potter, C. E. Shepard, all of Batavia; and Jay Lathrop, of Morganville. Following is the report of the committee:

"The first machines in the field were those in which no pumps were used for forcing the liquid. The only power used was the

force of gravity, the fluids passing downward from the tank to the outlet orifices. The Steitz potato sprayer was soon found to be working under disadvantage. The agitator broke almost at the moment of starting. The machine is designed to spray two rows at once ; the liquid runs over two broad pieces of galvanized iron, one being over each row, and then it is broken up into a fine spray by means of rapidly revolving brushes. The holes through



100.—*An excellent home-made potato sprayer, treating four rows.*

which the liquid passed upon the iron were too small, so that the plants were not properly covered. Another objection to the machine was found in the tank ; this was too small, and it could be increased two or three times its present capacity to advantage.

"The Studebaker machine was built on the pattern of a street-sprinkler. The mechanism forming the discharge was designed to be so constructed that any desired amount of liquid could be thrown in a fairly fine spray. The machine could not be made to work satisfactorily, as too much or too little liquid was thrown, and the spray was altogether too coarse for efficient and economical work. Even clear water was not thrown satisfactorily.

"The Aspinwall sprayer was then tried, the result being some-

what similar to that produced by the preceding machine. It clogged repeatedly, and proved to be unsuited to throwing Bordeaux mixture.

"A change was introduced with the appearance of Samms' machine, this being known as 'Roberts' Improved Atomizer.' It is designed to spray four rows. Three small streams of liquid left the machine over each row, but immediately upon leaving the discharge pipes, they were broken by blasts of air into an exceedingly fine spray which was well distributed over the plants. The machine worked admirably, and demonstrated its capability of spraying 4 rows of potatoes as fast as a walking team could draw it. The amount of liquid leaving the discharge pipes was found to be too small, but this defect could be easily remedied. Another objection was the cost of the machine, the price being $65.00.

"Power sprayers were represented by Deming's 'Monarch.' This is constructed so that five rows may be sprayed at once. A double-acting brass pump is worked by gearing, and it is sufficiently powerful to supply the nozzles, which are held over each row, with the required amount of liquid. The work of this machine was also very satisfactory. The spray was produced continuously, it was forcibly applied to the plants, and the amount of liquid thrown could be varied by the use of different nozzles. The 'Monarch' was one of the most useful machines exhibited; but its high price, $75.00, is an item which may discourage some from using it.

"The greatest sensation of the day, however, was occasioned by the appearance of the home-made sprayer of Potter and Ware. Figure 100 represents the appearance of the outfit. An ordinary barrel spray pump was fastened to a barrel having a capacity of about fifty gallons. The liquid was pumped into a gas-pipe which was supported upon a light frame at the rear of the wheels. This pipe was fitted with four discharges to which nozzles could be attached. Four rows were sprayed at once, the work being fairly well accomplished as the horse walked across the field. Mr. Ware drove and pumped at the same time, and the machine worked without a break. The plants were uniformly although rather lightly covered, and the machine was pronounced a decided success by the four or five hundred people who saw it in

operation. It should serve as a model to potato growers who desire this kind of an outfit.

"The Douglas and the Deming knapsack pumps were then brought into the field and both worked well. The pumps are sufficiently strong to force the Bordeaux mixture through Vermorel nozzles, and a very thorough application could be made. But the severe labor, and the slow rate of progress will prevent this type of machine from becoming popular for potato spraying. Myers' 'Fountain Knapsack Spray Pump' is a gravity sprayer, the liquid being forced through a perforated disk by means of a rubber bulb situated immediately behind it. Bordeaux mixture could not be applied with this device, as the holes in the disk clogged continually. When clear water is used, good work may be done.

"The powder guns of Leggett and of the Excelsior Co., did excellent work. They are easily worked and efficient. The only objection to them is that they treat but one or two rows at a time and this becomes a serious fault when large areas have to be treated. This objection is the more weighty when one considers that the most efficient applications of powders can be made only on a still day and when the foliage is wet.

"The other pumps which were exhibited were not tested in the potato field. The Deming and the Douglas pumps were found to be very strong, serviceable, and apparently durable, and with the proper attachments they could be made of service in spraying potatoes.

"In conclusion, it is the opinion of the committee that as a rule the best machines are those in which a pump forces the liquid through nozzles, so that a uniformly fine spray may be produced. Gravity machines, with the exception of 'Roberts' Improved Atomizer,' proved to be unsatisfactory, although the Steitz machine, if slightly modified, could be made serviceable.'

"Signed J. G. FARGO, Chairman.
E. D. RUMSEY.
J. H. POTTER.
C. E. SHEPARD.
JAY LATHROP."

SUMMARY.

1. Potato rot, or late blight, is caused by a fungus which may develop with extreme rapidity under favorable circumstances; it may cause the decay of all parts of the potato plant, including the tubers. (Page 249.)

2. The conditions favoring the growth of the parasite are a temperature of about 70° F. and a moist atmosphere. Few sections of New York are every year seriously troubled by the disease. (Page 250.)

3. A leaf affected by late blight normally shows distinct brown and mostly large areas of varying form, but usually not circular spots; these may enlarge very rapidly, the under surface of the leaf showing a frost-like growth in the parts first attacked. Unaffected portions of the leaves retain their healthy green color. (Pages 251, 252.)

4. Tubers affected with potato rot assume a dark color where the fungus is found. Where decay takes place slowly, the dead portions become dry and shrivelled; during rapid invasions considerable moisture may be present in the rot. (Page 353.)

5. The early blight of potatoes does not cause the tubers to rot. A more or less rapid drying and curling of the leaves and stems mark the presence of the disease. The edges of the leaves are first visibly affected; the color changes to yellowish brown, while the central parts of the leaflets gradually become lighter green or even yellow and more or less spotted. Eventually all portions above ground turn brown. (Pages 255, 257.)

6. Young, vigorous potato plants do not appear to suffer from early blight. (Page 257).

7. The probable causes of early blight, as found in New York, are the following: A fungus, this having the power of attacking only such tissues as have become weakened to a certain extent; unfavorable conditions of soil or atmosphere; mechanical injuries to the foliage, commonly produced by flea-beetles or other insects. (Pages 257, 261.)

8. Potato scab, as commonly found upon the tubers, is due to the presence of a fungus. Similar blemishes have also been

ascribed to the work of bacteria, and to insect injury. (Pages 261, 264.)

9. The late blight of potatoes may be successfully treated by spraying the vines two or three times with the Bordeaux mixture. The first application should be made during the latter part of July; it may be repeated at intervals of one to three weeks. (Page 264.)

10. The early blight of potatoes may be treated with partial success by means of the Bordeaux mixture. The vines should be sprayed when about two-thirds grown, and the application should be repeated as necessary, the foliage at all times being well covered with the mixture. (Pages 265, 271.)

11. Proper methods of fertilization and of cultivation have also proved to be of much value in reducing injury from early blight, as was shown by greatly increased yields. (Page 271.)

12. The apparent increased yield per acre of potatoes sprayed with the Bordeaux mixture was 44.8 bushels. (Page 270).

13. The increased yield per acre of potatoes well fertilized and cultivated, as compared with partially neglected plants, was 100 bushels per acre. (Page 271.)

14. Seed potatoes affected with scab may be cleaned and made fit for planting by soaking them in a solution of corrosive sublimate. (Pages 271, 272.)

15. An alkaline condition of the soil favors the growth of the scab fungus; an acid condition checks it.

16. Land in which the fungus causing potato scab is known to exist should not be used for growing potatoes or beets except at intervals of several years. Fertilizers which tend to produce an acid condition of the soil should be applied. Even treated seed will produce scabby potatoes, if the scab fungus is in the soil. (Pages 272, 273.)

17. Potato beetles may easily be destroyed by means of the arsenites. Paris green and London purple are the safest insecticides to use. (Pages 274, 275.)

18. Flea-beetles cannot be controlled satisfactorily. Bordeaux mixture thoroughly applied, appears to be the best practical remedy against these insects. This material probably does not kill the beetles, but simply keeps them away. (Pages 275, 276.)

19. In a comparative trial of many kinds of machines designed for spraying potatoes, it was found that those machines were unsatisfactory in which liquids are distributed wholly by the force of gravity.

20. Gravity sprayers are of value when the liquids are broken into a spray after leaving the discharge pipes. This may be done by means of air blasts or by revolving brushes.

21. Pumps for driving the liquids through nozzles are on the whole most satisfactory. They can be arranged so that several rows may be sprayed at once.

22. Horse-power sprayers can be recommended for spraying potatoes. If the plants are sprayed for the potato beetle, one nozzle over each row is sufficient; for flea-beetles and for fungous diseases, it is better to have two nozzles for each row, that a more thorough application may be made.

23. Powder guns are very satisfactory when insecticides are to be applied to potatoes, although wind and dry foliage may lessen the value of the treatments.

24. Fungicides should usually be applied in liquid form, using machinery which will treat the vines thoroughly as fast as a man or a horse can walk.

E. G. LODEMAN.